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REPORT

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NON-METALLIC PROJECTILE CARRIERS - PART 4

Discarding Projectile Carriers as Sabots for Launching Flechettes

BY

J. P. MC DONOUGH

H. W. HUGHES

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NON-METALLIC PROJECTILE CARRIERS - PART 4

Discarding Projectile Carriers as Sabots for Launching Flechettes

WAL NO. 762/523-3 (c)

O.O. Project No. TA1-5003

By

J. P. MC DONOUGH
Proof Technician

E. N. HEGGE
Mechanical Engineer

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Authorized by: Sub-Order 207-53 (Picatinny Arsenal)
O.O. Project No.: TA1-5003
Report No.: WAL 762/523-3 (c)
Title of O.O. Project: Canister Pellets in 40 MM Gun Ammunition System

TITLE

NON-METALLIC PROJECTILE CARRIERS - PART 4

Discarding Projectile Carriers as Sabots for Launching Flechettes

OBJECT

To design and develop a Watertown Arsenal Laboratory Type Carrier suitable for launching flechettes weighing 8.02 grains into free flight from smooth bore gun tubes, singly, and as components in experimental loadings of small scale multi-missile (canister) shot.

SUMMARY

This report describes the ballistic performance and data on a series of WAL Type Discarding Projectile Carriers designed for launching flechettes, weighing 8.02 grains, into free flight from smooth bored gun tubes. The ballistic tests herein described also include the development of a technique for recording the losses in linear velocities of the flechettes over the flight distances of 30, 100 and 200 feet. Tests were also made to compare the losses in velocities and probable terminal accuracy of flechettes having slight modifications of their nose (ogives) and fin bases. Measurements were made of the depth of penetrations of standard and modified flechettes into a composite target of soft pine wood. Also, studies were made of the flight characteristics, stability and performance of standard, as well as modified, flechettes by means of measurements and observations of their passage in flight through a series of specially designed and constructed witness panels, mounted at 30, 100 and 200 feet distances from the muzzle of the gun tube, as well as by means of spark photographs of the flechettes in flight, singly, and in experimental multi-missile loadings.

CONCLUSIONS

From the observations made in these tests, it is concluded that:

1. The WAL Type Carrier can be successfully used to launch flechettes into free flight singly from a smooth bored gun tube

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2. The WAL Type Carrier can be applied to the experimental and developmental ballistic evaluation of flechettes or other similar missile types that may be under consideration as potential fillers for multi-missile (canister) type ammunition.

John P. McDonough
J. P. MC DONOUGH
Proof Technician

E. N. HEGGE
Mechanical Engineer

APPROVED:

J. L. Martin
J. L. MARTIN
Director of Laboratory

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INTRODUCTION

The development of the Watertown Arsenal Laboratory Nonmetallic Projectile Carrier, Discarding Type, was an indirect result of a long range, hyper-velocity, armor-piercing shot program initiated by the Office, Chief of Ordnance in 1945.

In the development of this type of carrier, numerous types of non-metallic materials were used experimentally. Ballistic analyses and comparisons were made in the evaluation of possible carrier materials. Carrier sizes varied from 0.226 inch to 3 inches and the sub-projectiles consisted of many types, ranging in size from 0.150 inch to 2 inches. Much of the test work has been accomplished by using scale models of cannon ammunition as sub-projectiles mounted in these types of carriers, and several reports have been prepared and submitted.[1,2,3,4]

Based upon this prior knowledge, it was apparent that the WAL Nonmetallic Projectile Carrier could be successfully used as a method to obtain precise exterior and terminal ballistics data of the performance of flechettes fired singly, as well as in experimental multi-missile loadings. Therefore, at the request of Office, Chief of Ordnance (ORDTS), a preliminary test series was outlined, as herein reported. The carrier type used in these tests was essentially a basic carrier design that has been successfully used at Watertown Arsenal Laboratory to launch small (2 grain) and medium sized (45 grain) shell fragments and fragment simulating projectiles into free flight from both smooth and rifled gun tubes.[5]

1. Report Nos. WAL 762/532, 762/532-1 and 762/532-2, "Nonmetallic Projectile Carriers", by E. N. Hegge and J. P. McDonough.
2. WAL Technical Services Branch Report No. 52-8, "The Ballistic Behavior of Special Projectiles and Missiles Fired in WAL Nonmetallic Projectile Carriers", by J. P. McDonough & H.A. Traverse.
3. Aberdeen Proving Ground 4th Report, OCO Project No. TA1-1302, First Development of Shot, HVAP-DS, 76/50mm, by J. R. Tomlinson.
4. Report No. WAL 761/59, "Preliminary Investigation of WAL Type Discarding Projectile Carriers as Applied to Small Arms Projectiles", by J. P. McDonough and A. Sloan.
5. These applications of the WAL Type Carrier have been developed by the WAL Ballistics Section to fire missiles which are used to evaluate and compare materials being considered by the Ordnance and Quartermaster Corps to serve as armor for personnel.

DISCUSSION OF TEST METHODS AND RESULTS

THE TEST WEAPON:

To launch the flechettes into free flight, singly, from the WAL Type Carriers, a test weapon was developed from an M 1922 Springfield Armory barrel, caliber 0.226 inch. This barrel was then smooth bored and hand lapped to 0.270 inch ±0.001 inch. This tube was then chambered to accomodate a caliber .300 H and H Magnum cartridge case.

In the experimental firings of the flechettes, as components in the experimental multi-missile rounds, a caliber 0.50 inch test barrel was smooth bored and hand lapped to 0.527 inch ± 0.001 inch. The chamber of this tube was not modified; therefore, the Service case, M1 caliber .50, was used as the propellant container.

THE PROPELLANTS:

In the .270/300 firing tests (flechettes launched into free flight singly) the propellant selection was Hercules Unique. Propellant IMR No. 4759 was the selection in the caliber .50/.527 inch (experimental multi-missile firings).

The test weapons were, in all instances, parallel boresighted, and the test rounds were fired as semi-fixed ammunition. The firing mechanism was a Frankford Arsenal universal type.

THE WAL TYPE CARRIERS:

The experimental designs (A, B, C and D, Figure 1) of this report, were prepared from extruded rods of methyl methacrylate (lucite). The carriers were then carefully lathe turned from this material to the prescribed dimensions. Inherent dimensional errors in uniformity of the flechettes as received made it necessary to hand fit the individual carriers and flechettes prior to firing (except in the case of the experimental multi-missile firings).

In the preliminary firing tests, on final assembly, the bases of the carrier were wound with two circumferential wrappings of cellulose tape 0.250 inch in width. The inclusion of this wrapping was to accomplish obturation of the carriers within the bores of the tubes and to eliminate the initial escapage (blowby) of the propellant gases, and thus improve the reproducibility in the round to round relationship between propellant charge vs flechette velocity. This obturation of the carriers within the gun bore could also have been accomplished by an increase in the diameter of the lower base portion of the carrier by approximately 0.005 inch.

THE VELOCITY RECORDING APPARATUS:

To record the primary and secondary velocities of the flechettes in free flight, two Potter type 400 H.C. Counter Chronographs were employed as follows: actuated by two independent pairs of photo-electric cells (triggers), having a 20 foot baseline (interval between triggers) and mounted at the prescribed distances of 30, 100 and 200 feet measured as the mid-point distance between the pairs of triggers. Therefore, one chronograph was used to record the initial flechette velocities and the other chronograph would necessarily record the residual velocities of the flechettes in free flight.

THE WITNESS TARGETS:

As a method to assist in the analytical evaluation of the down range and terminal ballistics performance of the flechettes in free flight, a special type of witness target was prepared, consisting of 20 inch x 20 inch wooden frames. These frames were then covered with thin kraft paper and finally given a coating of thinned shellac. These targets were then located at predetermined distances from the muzzle of the gun tube. Targets of this type will permanently indicate any erratic flight behavior or deviation of this missile from its true line of sight.

THE PINE BOARD TARGET:

To insure reliable and reproducible penetration results, a target was prepared from a single length of knot free, dry, soft pine board, 8 inches in width and 1-3/4 inches in thickness. This pine board was then finally planed to exactly 1-3/8 inches in thickness and the penetration target was made up of sections of this material. In this manner, a uniform pine target was assured.

THE SPARK PHOTOGRAPHY:

The shadowgraph data, depicting the aerodynamic behavior of flechettes in flight singly, as well as in multiples, was produced with an apparatus consisting of a spark source, associated time delay equipment, and power supply, designated Spark set H.V. Spark Unit (Aberdeen Proving Ground design). The unit has controls for varying the time delay over a range of 70 to 800 micro-seconds. A WAL Type Triggering Grid was used to actuate this spark source.[1,2]

OBSERVATIONS AND CONCLUSIONS

THE WAL TYPE CARRIERS:

The initial firing tests with standard flechettes, mounted in the carrier type, shown as A, Figure 1, resulted in erratic flight performance of the standard flechettes. This was clearly demonstrated by the initial indications of excessive yawing, as was disclosed by the witness target penetrations as well as from the relatively poor dispersions obtained upon the terminal impact targets. It was, therefore, concluded, that on set-back of the flechettes within the carriers, the curved base cavities would tend to compress at the leading edge, and in this manner, unduly grasp or bind and thus induce a delay, or non-symmetrical discardment of the carriers from the flechettes. This binding of the carrier base would tend to induce excessive yawing in flight.

Because of the poor performance of the type A carrier, a flat base cavity design, as shown in B, Figure 1, was tried. The flechettes were also modified by squaring off the fin bases. These changes resulted in an appreciable improvement in the exterior ballistic performance of the flechettes. However, in some instances, it was observed that an occasional erratic flight performance of a flechette would occur. Evaluation of the witness target results, and from a careful study of the first shadowgraph pictures obtained, it was concluded that type B carrier was not effectively supporting the shaft (body) of the flechettes and that balloting was occuring in some instances within the gun bore. This balloting would necessarily induce erratic flight and the flechettes would travel considerable distances before the fins could straighten out the trajectory of the missile.

---

1. Report No. WAL 892/11, "Development of Technique for Spark Photographs of Projectiles in Flight" by Lt. Col. S. H. Walters, Ord Corps, USAR.
2. Report No. WAL 762/523(c), "Nonmetallic Projectile Carriers" by E. N. Hegge and John P. McDonough.

In order to support or guide the shaft (body) of the flechette in the gun, the design shown as type C, Figure 1, was evolved. This carrier consisted of two parts, a base piece with slots 120° apart into which the fins of the flechette fitted and a cylindrical tube which fitted over the shaft (body) of the flechette. This design resulted in a slight improvement of the terminal accuracy as well as some reduction of the initial yawing of the flechettes in flight. However, not enough actual firing results were obtained with either the type B or C carriers to determine conclusively a positive preference for either type. A plot of flechette dispersions launched into free flight from the B and C type carriers is shown in Figure 5.

Tests of flechettes, loaded as components for experimental multi-missile ammunition, were made by loading the flechettes into the carrier design shown as D, Figure 1. In the multi-missile firings, 13 flechettes were loaded in the carrier having their shafts parallel and fin bases resting on the base of the carrier. A compression band around the bodies of the missiles was used in some firings but it was not positively established that this compression band did, or did not, improve the missile dispersions. However, a band of this type should reduce the possibility of the flechettes balloting in the gun bore and thus effect an improvement in the beyond-the-muzzle performance of flechettes.

THE VELOCITY LOSSES:

It was apparent that the drop off in velocities during the first 30 feet of travel was, in many instances, excessive as compared to the recorded 100 and 200 foot losses in velocity. The initial (or near the muzzle) yawing of the flechettes in flight would necessarily influence this rather excessive deceleration, as shown in Figures 2, 3 and 4. Table I has been prepared as additional information providing direct comparison of losses in velocity.

THE PINE BOARD PENETRATIONS:

Although the pine board penetration results, as given in Figure 6 of this report, were based on an assured uniformity of the penetration target, it appears that such penetration results are not a good criterion in the final evaluation of the lethal potential of any given missile or projectile. Since there are a large variety of types of "pine boards", each having variables in age, density, thicknesses and moisture content, it appears that the "pine board" comparison is not a good lethality test, and the results should, therefore, be used with caution, since variations in the target may reduce the true effective range in one case and increase it in the other.

THE FLECHETTES:

The weight of the standard flechettes as received was 8.02 grains. The modifications to the fin bases resulted in a reduction in this original weight to 7.80 grains and modifications made on both the fin bases and noses of the flechettes further reduced the total weight to 7.49 grains. (These weights are based on an average of 10 randomly selected flechettes).

In the as-received condition, it was determined that the standard flechettes were comparatively non-symmetric in their geometries. This non-uniformity was apparently the result of the die forming processes in their manufacture, particularly so in the formation of the noses (ogives) of the flechettes and in their fin structures. Measurements of the fin dimensions further disclosed that the width of the three individual fins of each flechette varied in thickness from 0.012 inch to 0.015 inch and that the height of the crest of the fins, as measured from the outside diameter of the shaft opposite the crest, varied from 0.054 inch to 0.069 inch.

It was also observed that in the formation of the flechette noses (ogives) the hexagonal die cutting was somewhat uneven and, therefore, contributed to the formation of residual burrs and ridges upon the noses of the flechettes. These dimensional variables, particularly those observed in the fin and nose structures of the flechettes, would seem to be of sufficient magnitude as to produce an error in the uniform distribution of mass along the longitudinal axis of the flechettes, resulting in the ballistic unbalancing of the flechettes. This alone would seem to account for some of the inaccurate flight performances and excessive initial yawing of the flechettes in free flight as observed in these tests. This effect is clearly demonstrated in Figures 7 and 10 of this report.

There were no observed indications of physical failures (collapse of the fin bases of the flechettes) from the forces of set-back within the carriers, however, within the velocity range of 3600 F/S to 4000 F/S it was observed, that at the junction of the shaft and forward portion of the fin structure the fins would bend and assume a permanent "set". On closer examination, it was determined that this zone (the junction of shaft and fin) was inherently weak as a direct result of the die forming process in manufacture.

The accuracy of the flechettes was carefully observed throughout the tests, and, on the basis of the initial test results, it was apparent that a velocity range of from 2200 to 2700 feet per second is the most effective zone of accuracy for the design of the flechettes fired when launched into free flight from the B and C type carriers.

The comparative penetration results, obtained with standard and modified flechettes, as given in Figure 6, do not necessarily indicate a choice in the selection of the 1 caliber (standard ogive) flechette in performance to a 2 caliber (modified ogive) flechette, as modifications reduce the total mass from 8.02 grains to 7.49 grains. It was also observed that the modified flechettes would tend to dive during their penetrations of the target. However, in view of the limited test results, no conclusive estimates of comparative penetration performances can be made.

<u>THE SHADOWGRAPH PICTURES</u>:

As shown in Figures 7 to 15 of this report, the aerodynamic performance of the flechettes, launched singly, and as components in the experimental multi-missile rounds, was generally good. The major and secondary shock waves were, in effect, symmetrical. However, above Mach No. 1, the errors in manufacture (as described in the discussion of the flechette herein) can be readily observed. This effect is clearly demonstrated in the arrangement and intensity of the bow waves acting upon the noses of the flechettes in flight. Here the effect of the hexagonal die cutting is graphically reproduced. Also, the small residual burrs and scratches upon the leading and trailing edges of the fins have set up secondary retarding forces that influence the flechettes in flight.

The spark photographs (shadowgraphs) of the flechettes, launched as experimental multi-missile rounds, in plastic carriers, are shown in Figures 11 and 12 of this report. Below the velocity of sound in air (Mach No. 1) the 13 flechettes were still in a compact group at 12 feet distance from the muzzle of the gun tube. As can be seen in Figure 11, the compression ring, that originally fitted over the noses of the 13 flechettes (D, Figure 1), had become disengaged prior to this distance. The dispersion of the flechettes at 50 feet distance from the muzzle of the gun tube was evenly distributed within a diameter of approximately 19 inches. At the higher velocity, 1900 feet per second, the outer rings of the flechettes were beginning to fan out, as can be seen in Figure 12, and sections of the fractured compression ring have discarded and are trailing the flechette group. The dispersion of the flechettes fired at the higher velocity was approximately twice that of the flechettes fired at the lower velocity and in addition several of the flechettes were yawing excessively at the higher velocity. It is apparent from this spark photograph that prior to separation of the flechettes from the base of the plastic carrier, the built up air pressure within the assembled group forces the nose ends of the missiles to fan out.

Figures 13, 14 and 15 of this report are shadowgraphs depicting the exfoliation of an experimental 12 Ga. multi-missile round.[1]

DISCUSSION AND RECOMMENDATION

The results of experimental work described in this report indicate that further work in this direction would be justified. This further work would cover a broader range of testing program and should, therefore, include the following:

1. By the process of injection molding, the WAL Type Carriers could be manufactured to prescribed dimensions. This would effect an appreciable saving in both time and costs.

2. Any new tests of this type that may be contemplated should also include measurements of the losses in linear velocities of the flechettes in free flight and particular consideration should be given to the effects of variables, such as changes in the atmospheric conditions during such tests.

3. Modifications to the noses and fins of the flechettes should be given further consideration, and close controls should be established

1. The development of this experimental round is the direct result of an independent research program being conducted by Mr. John Bird of the Office of the Chief of Ordnance, ORDTS.

and maintained during the manufacturing processes. Especially important would be experimental studies of flechette "stacking" arrangement and methods of separation.

4. The pine board penetration standard of comparison should be discontinued as a test method in the evaluation of the lethal effect of flechettes. A more reliable penetration evaluation test might be established using targets of bonded and unbonded woven nylon laminates and other similar types of materials.

5. The shadowgraph picture studies should be broadened so as to include "in series" (multiple) views of the flechettes in flight. The inclusion of two-dimensional shadowgraph pictures would improve the analytical evaluation of the flight performance of individual flechettes.

From the observations made in these tests, it is concluded that:

1. The WAL Type Carrier can be successfully used to launch flechettes into free flight singly from a smooth bored gun tube.

2. The WAL Type Carrier can be applied to the experimental and developmental ballistic evaluation of flechettes or other similar missile types that may be under consideration as potential fillers for multi-missile (canister) type ammunition.

ACKNOWLEDGEMENT

The Authors wish to make the following acknowledgements:

To Mr. John Bird of the Office, Chief of Ordnance, ORDTS, for his expert technical assistance in the preliminary planning relative to the scope and range of ballistic data to be incorporated into the initial tests. Also, for his many valuable technical contributions in the analysis of the performance of the flechettes based upon his prior knowledge obtained in extensive independent research in the study and evaluation of the ballistic performance of flechettes as components for experimental multi-missile ammunition.

To Mr. Charles E. Dugas, Mr. Hugo A. Traverse and Mr. Stephen J. Doherty 111, of the Watertown Arsenal Laboratory Ballistics Section for their assistance in carrying out these firing tests.

TABLE I

INSTRUMENTAL VELOCITIES

At 30 Feet

Standard Flechette Plotted in Figure 2			Modified Flechette Plotted in Figure 3		
Initial Velocity	Secondary Velocity	Loss	Initial Velocity	Secondary Velocity	Loss
1015	980	35			
1805	1710	95	1680	1615	65
2215	2120	95			
2315	2255	60	2390	2325	65
			2410	2290	120
2470	2315	155	2415	2365	50
2645	2580	65	2570	2525	45
2680	2545	135			
2680	2575	105			
2685	2510	175			
2700	2570	130			
2710	2545	165			
2725	2500	225			
2780	2680	100	2855	2720	135
2945	2820	125	2890	2765	125

TABLE I (cont'd)

Standard Flechette Plotted in Figure 2			Modified Flechette Plotted in Figure 3		
		At 100 Feet			
Initial Velocity	Secondary Velocity	Loss	Initial Velocity	Secondary Velocity	Loss
865	785	80			
1385	1215	170	1330	1195	135
1435	1250	185			
1700	1500	200	1605	1425	180
1740	1470	270			
1840	1605	235			
2085	1840	245			
2140	1885	255	2150	1940	210
2260	2000	260			
2395	2115	280			
2395	2135	260			
2425	2155	270			
2430	2155	275			
2450	2175	275			
2480	2160	320			
2520	2300	220			
2620	2335	285			
2630	2315	315			
2630	2340	290			
2650	2310	340			
2660	2390	270	2900	2670	230
		At 200 Feet			
2460	1980	480	2380	1945	435
2570	2030	540	2550	2120	430
2705	2165	540	2595	2175	420
2850	2285	565			

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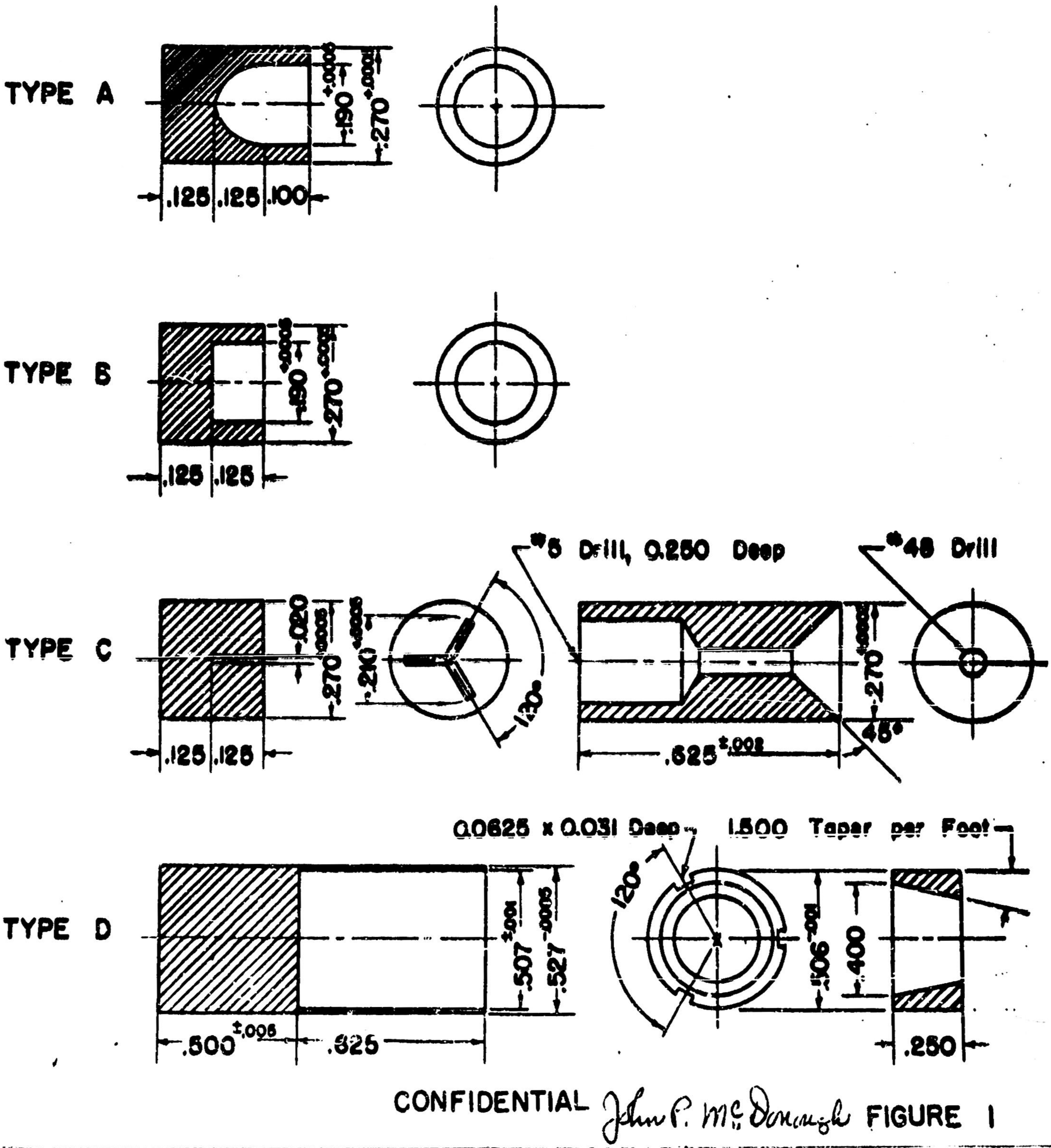
EXPERIMENTAL W. A. L. TYPE CARRIER DESIGNS DEVELOPED FOR LAUNCHING FLECHETTES INTO FREE FLIGHT



CONFIDENTIAL John P. McDonough FIGURE 1

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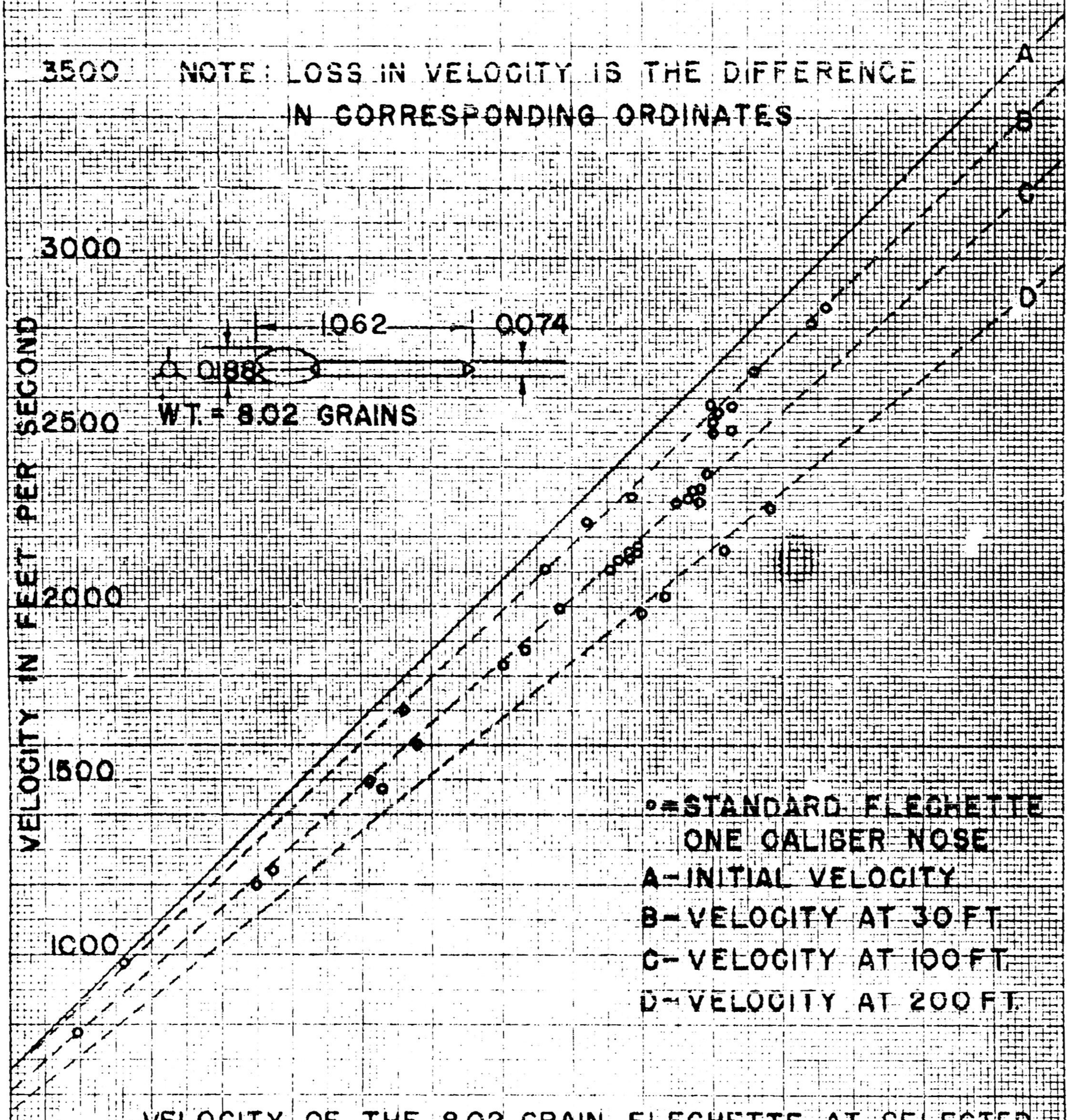

VELOCITY OF THE 8.02 GRAIN FLECHETTE AT SELECTED RANGES FOR VARIOUS INITIAL VELOCITIES

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FIGURE 2.

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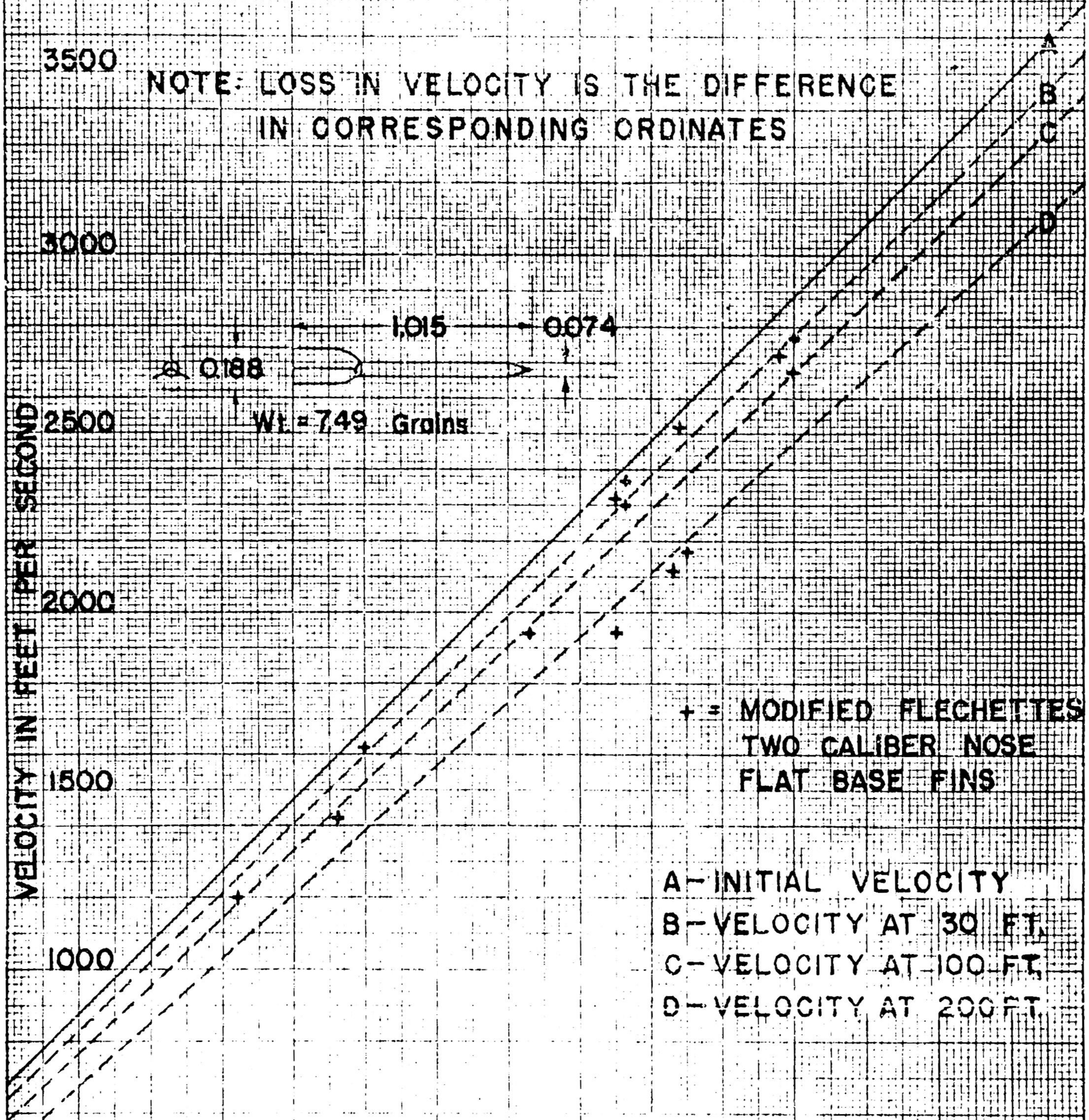

VELOCITY OF THE 7.49 GRAIN FLECHETTE AT SELECTED RANGES FOR VARIOUS INITIAL VELOCITIES

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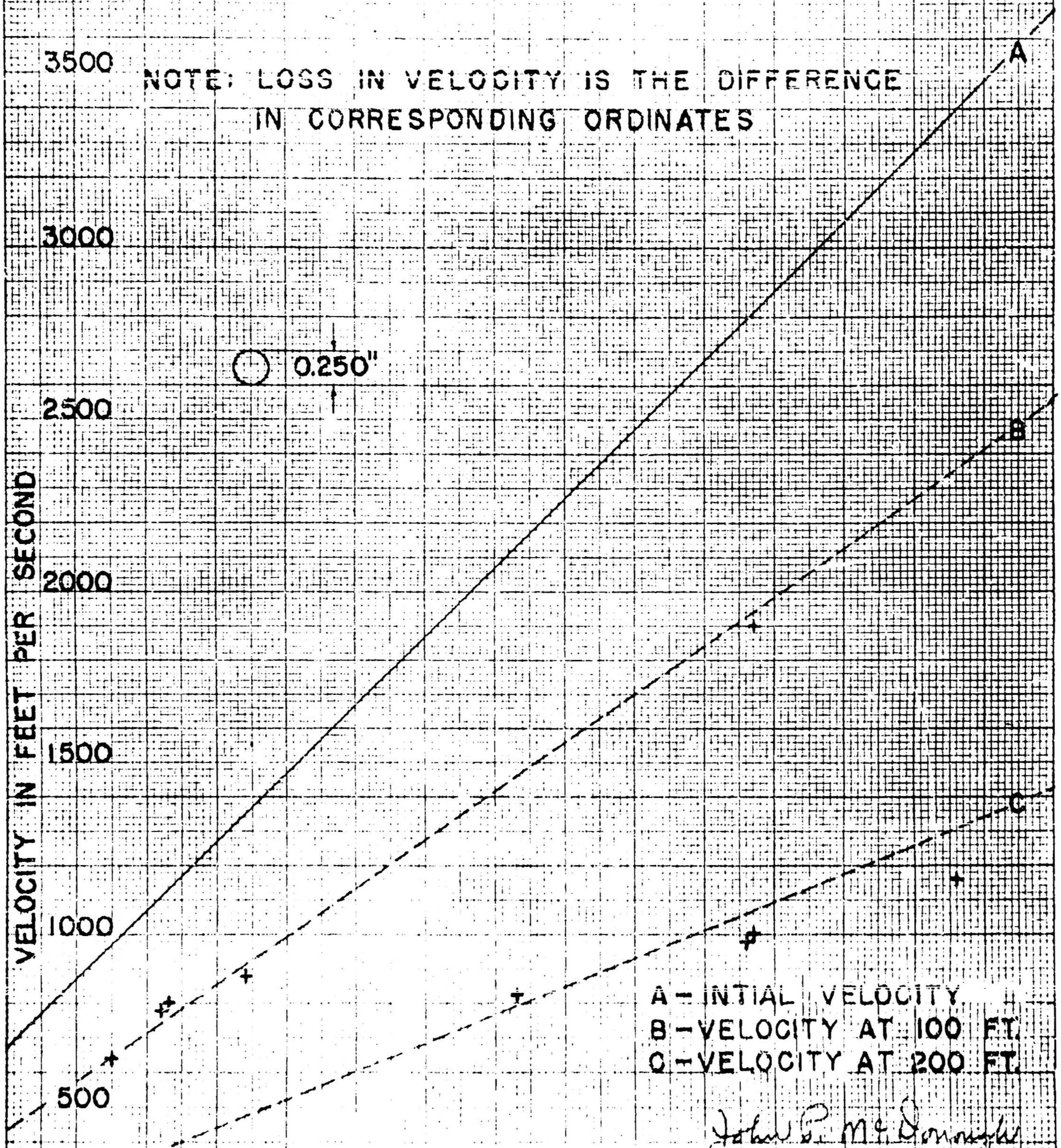

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VELOCITY OF THE 16.5 GRAIN, 0.250" SPHERE AT SELECTED RANGES FOR VARIOUS INTIAL VELOCITIES

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FIGURE 4

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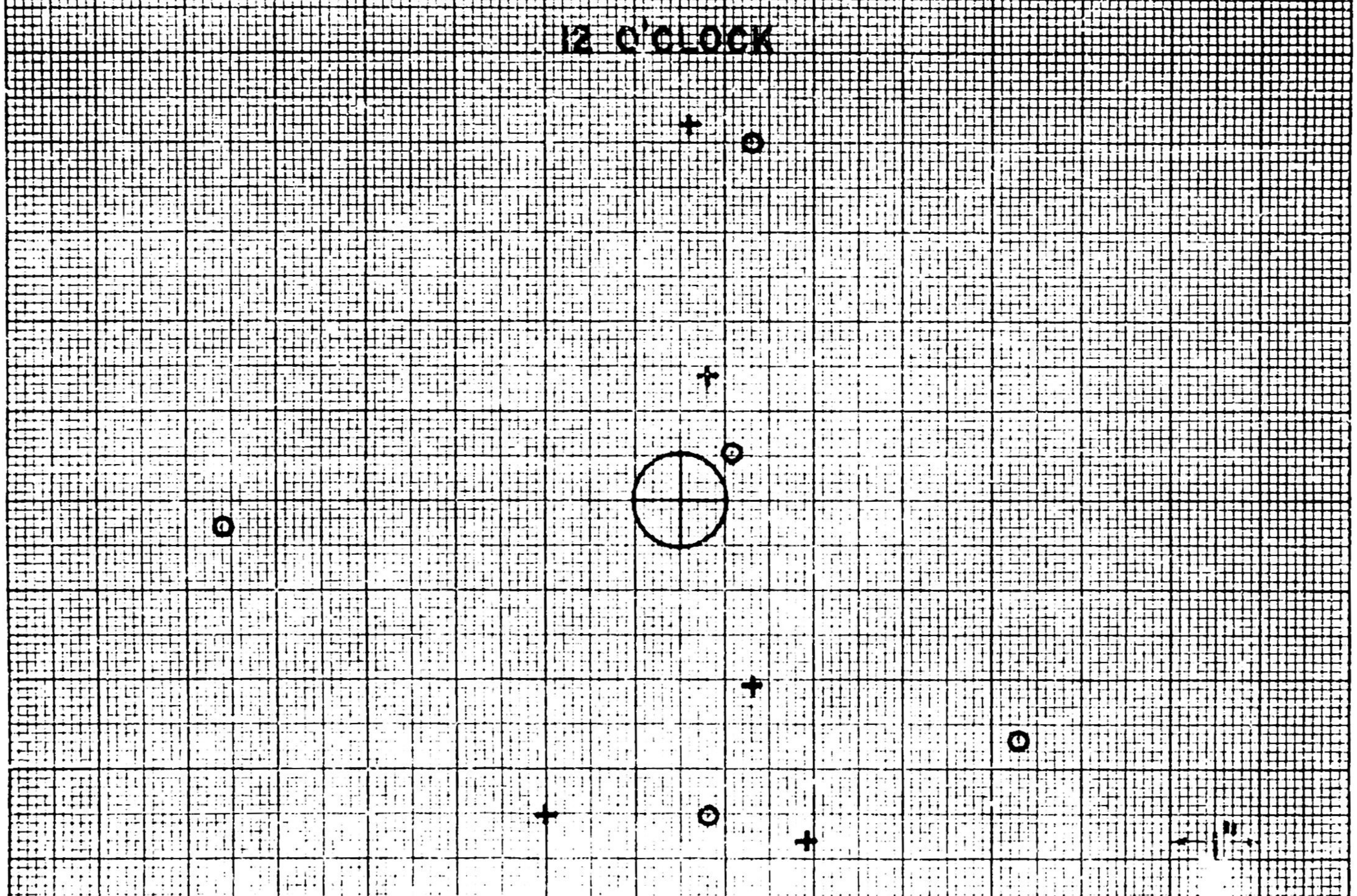

TARGET DISTANCE 100 FEET

COMPOSITE TARGET
GIVING DISPERSION OF 7.80 GRAIN FLECHETTES
VELOCITY RANGE 2215-2450 F/S
O= CARRIER TYPE "B"
+= CARRIER TYPE "C"
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FIGURE 5

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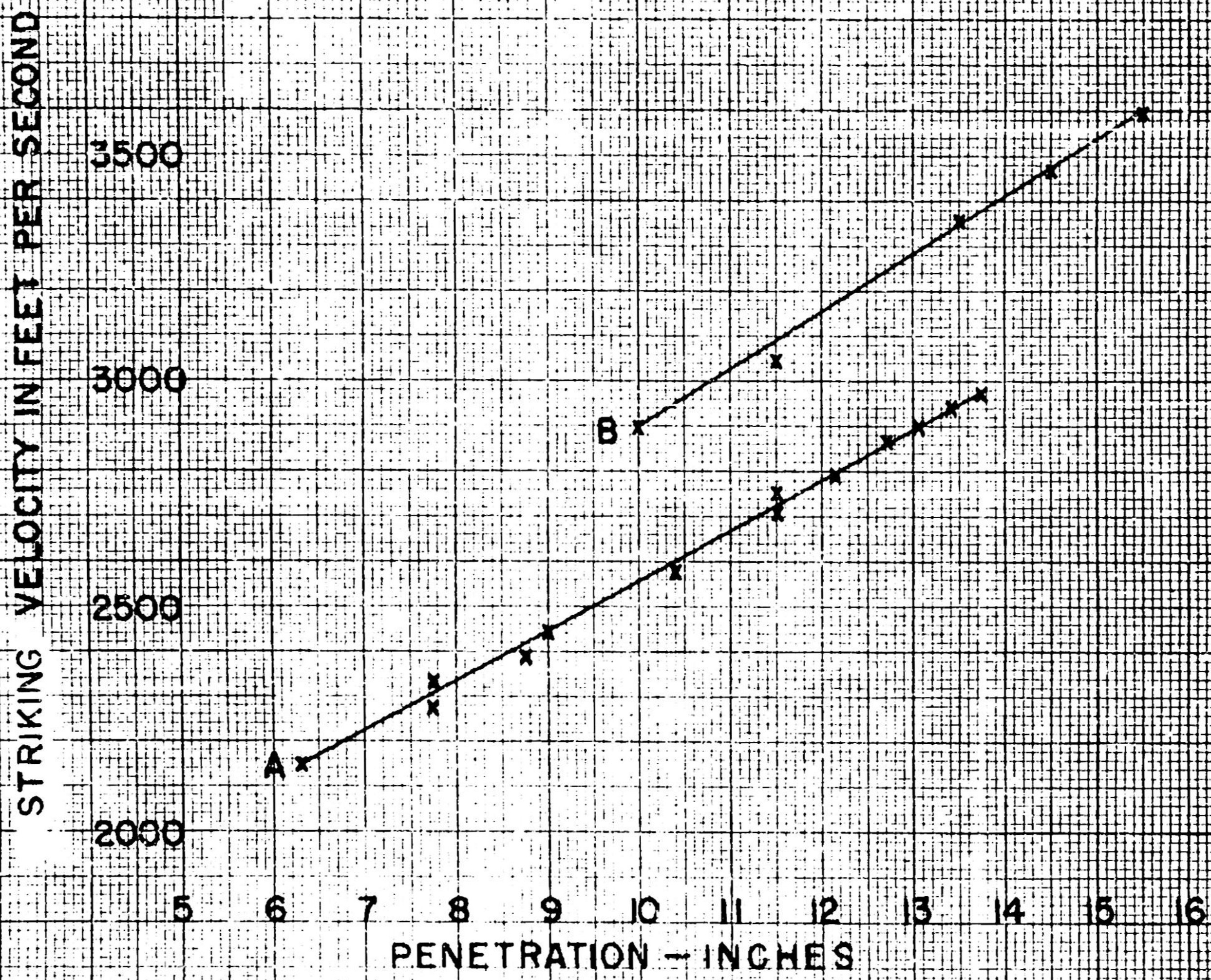

FLECHETTE VELOCITY VS. PENETRATIONS INTO SOFT PINE IN INCHES.
A= STANDARD FLECHETTE (1 CALIBER OGIVE) WGT. 7.80 GRAINS
B= MODIFIED FLECHETTE (2 CALIBER OGIVE) WGT. 7.49 GRAINS

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FIGURE 6

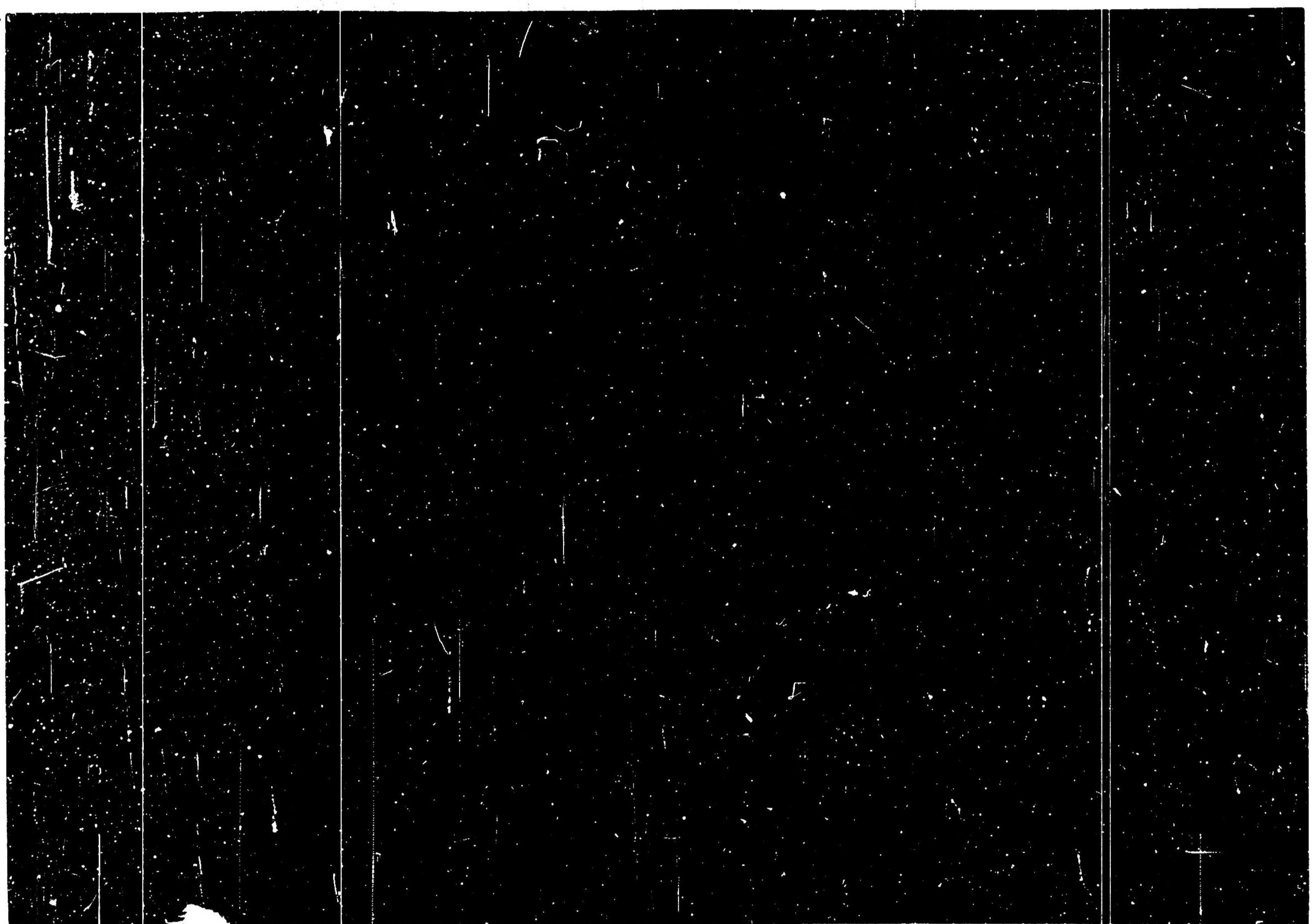

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FIGURE 7 – STANDARD FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY -- 2560 F/S.

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FIGURE 8 – MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 2655 F/S.

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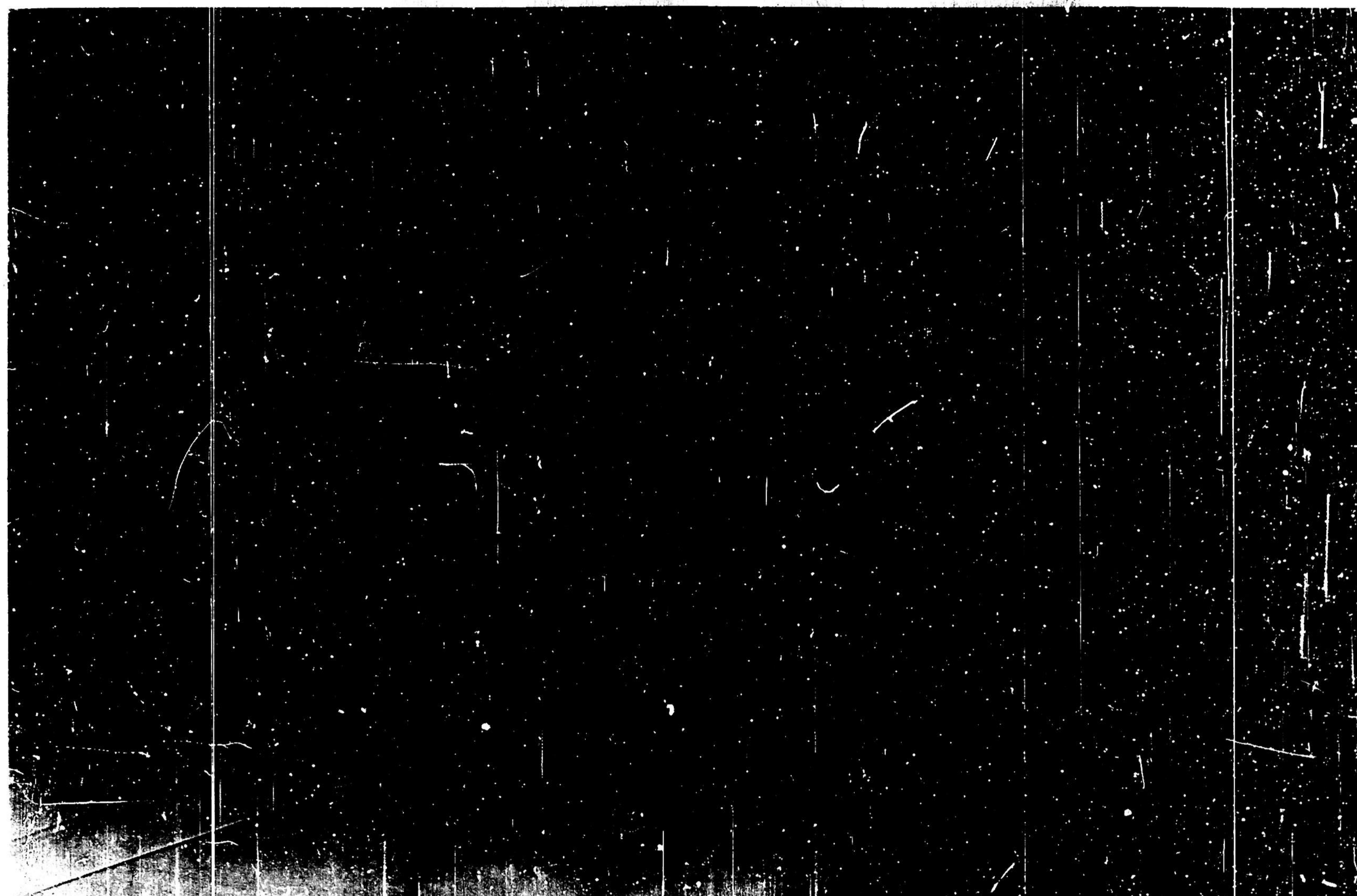

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FIGURE 9 – MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 3495 F/S.

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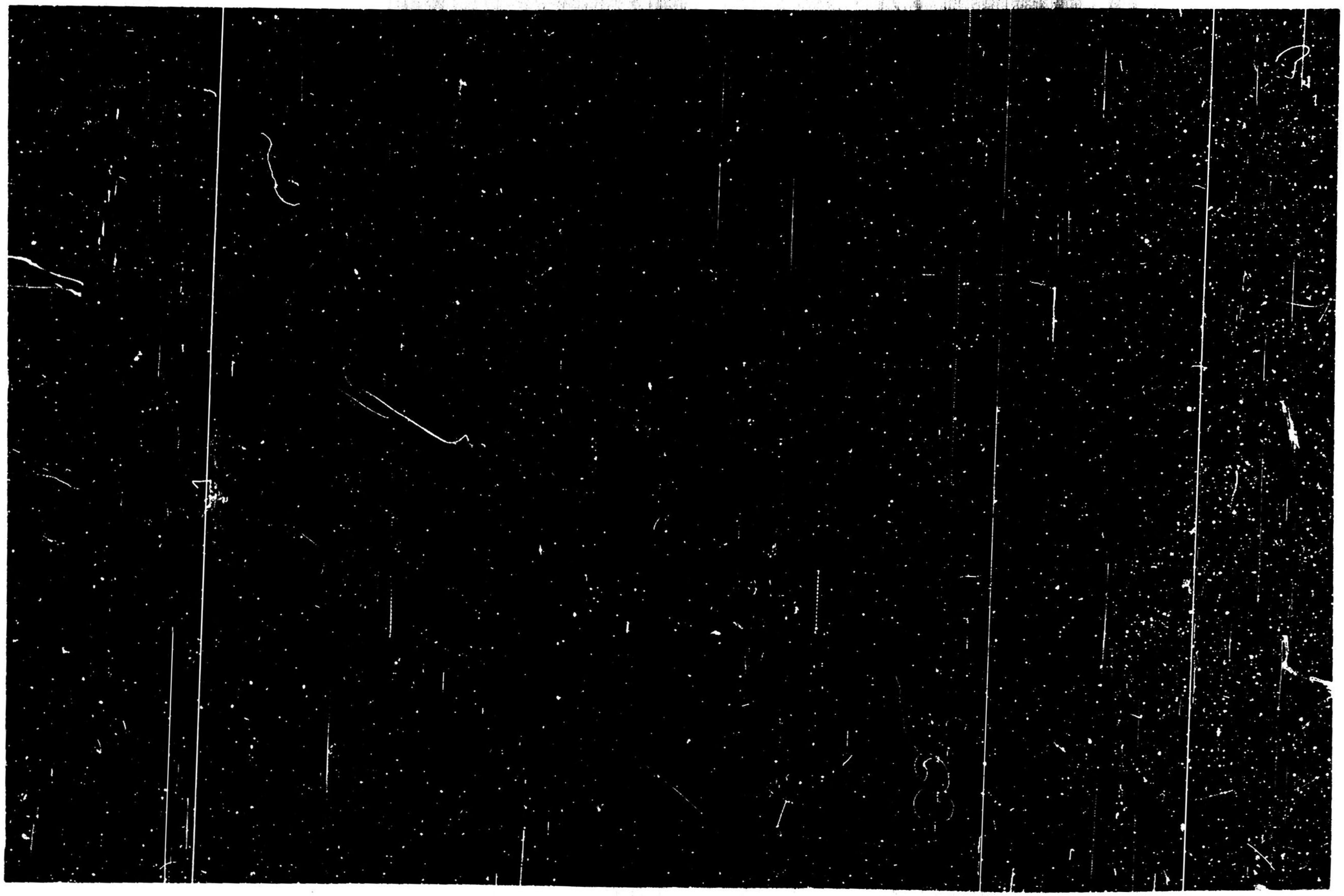

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FIGURE 10 – MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 3640 F/S.

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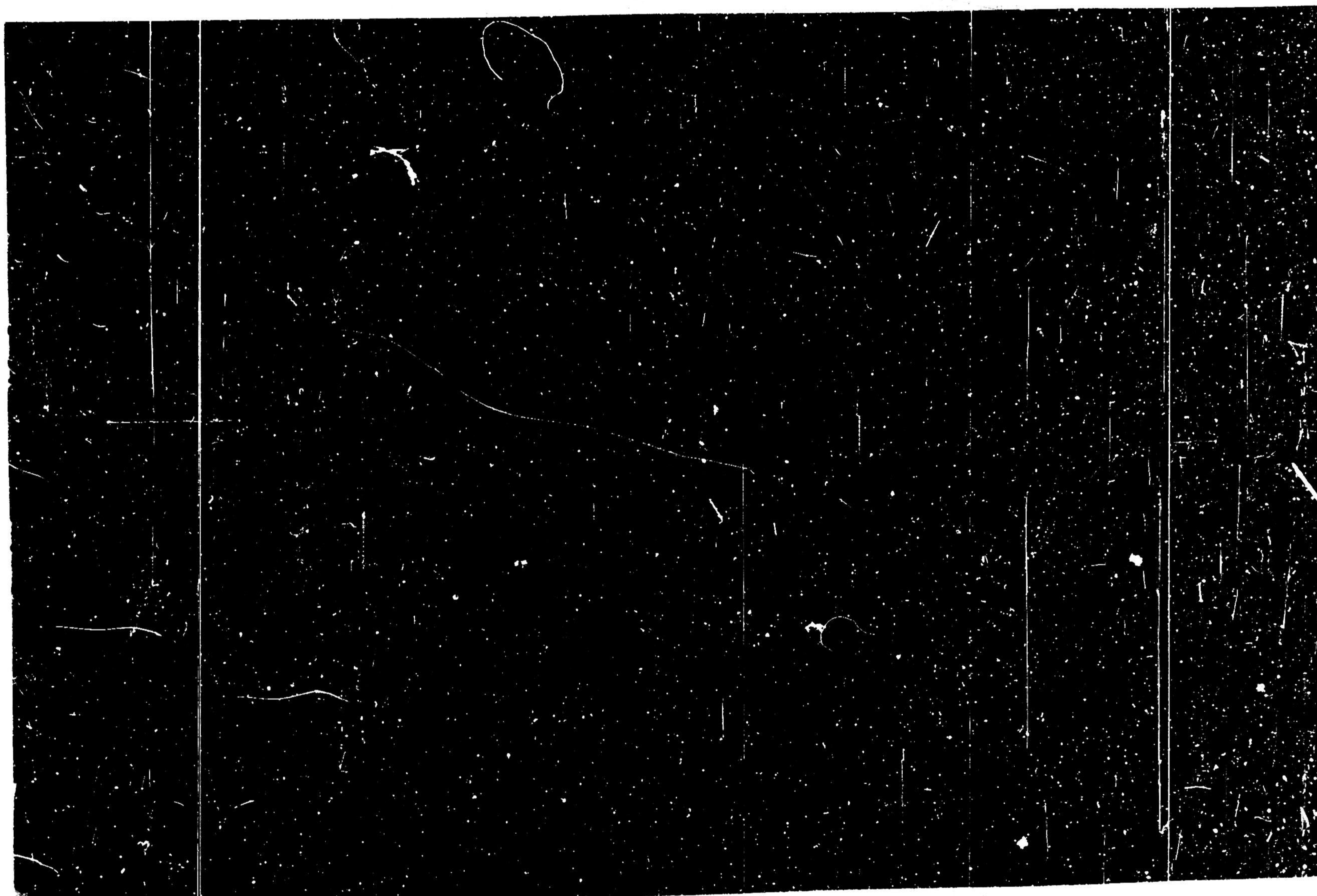

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FIGURE 11 – EXPERIMENTAL CALIBER 0.528" MULTI-MISSLE SHOT, CONTAINING 13 FLECHETTES, SHOWING ARRANGEMENT AT 12 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE; VELOCITY – 1100 F/S.

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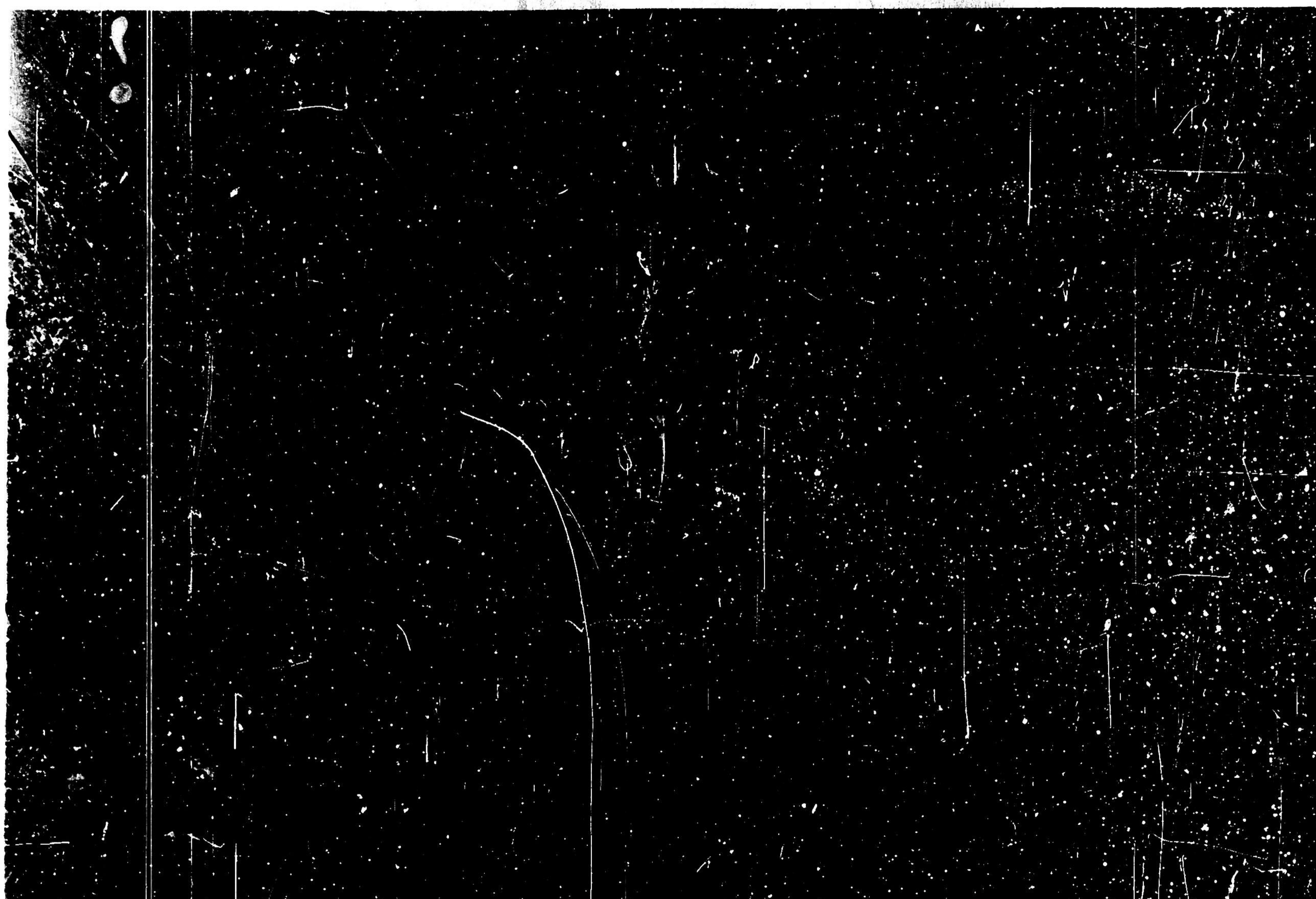

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FIGURE 12 – EXPERIMENTAL CALIBER 0.528" MULTI-MISSLE SHOT, CONTAINING 13 FLECHETTES, SHOWING ARRANGEMENT AT 12 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 1900 F/S.

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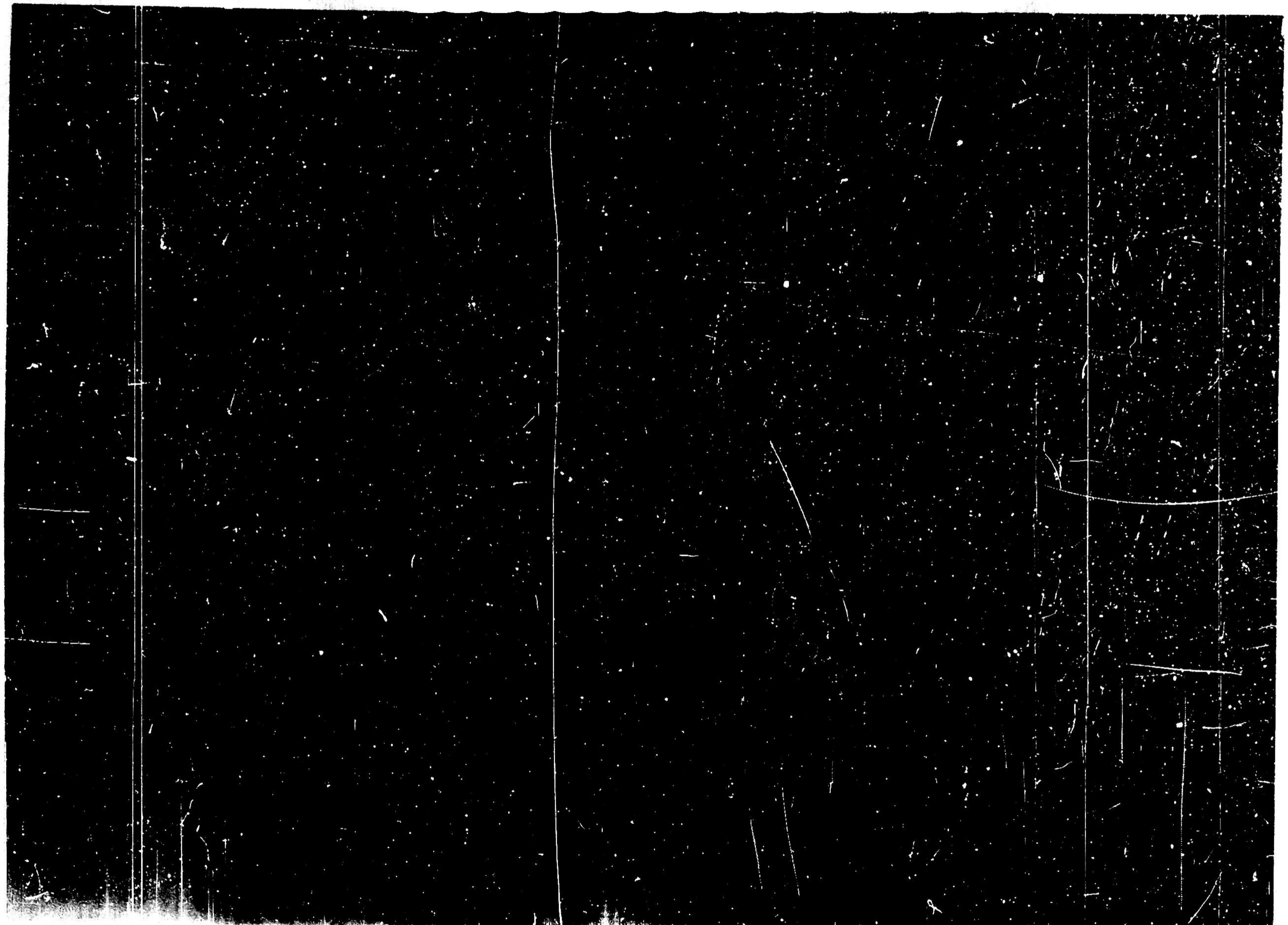

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FIGURE 13 – EXPERIMENTAL 12 GA. MULTI-MISSLE SHOT, CONTAINING 26 FLECHETTES, SHOWING ARRANGEMENT AT 3 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE.

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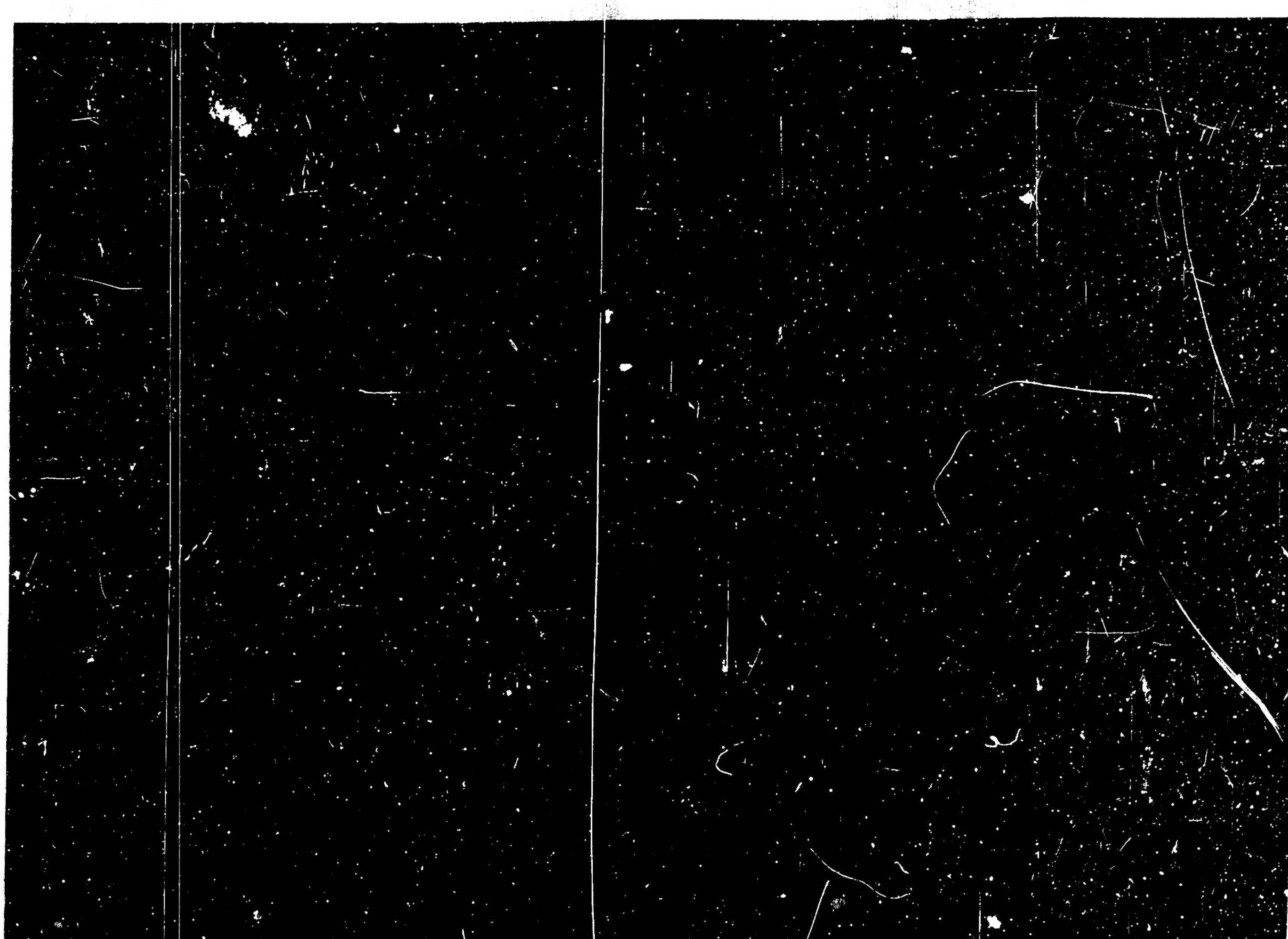

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FIGURE 114 – EXPERIMENTAL 12 GA. MULTI-MISSLE SHOT, CONTAINING 25 FLECHETTES, SHOWING ARRANGEMENT AT 4.5 FEET DISTANCE FROM THE MUZZLE OF THE GUN.

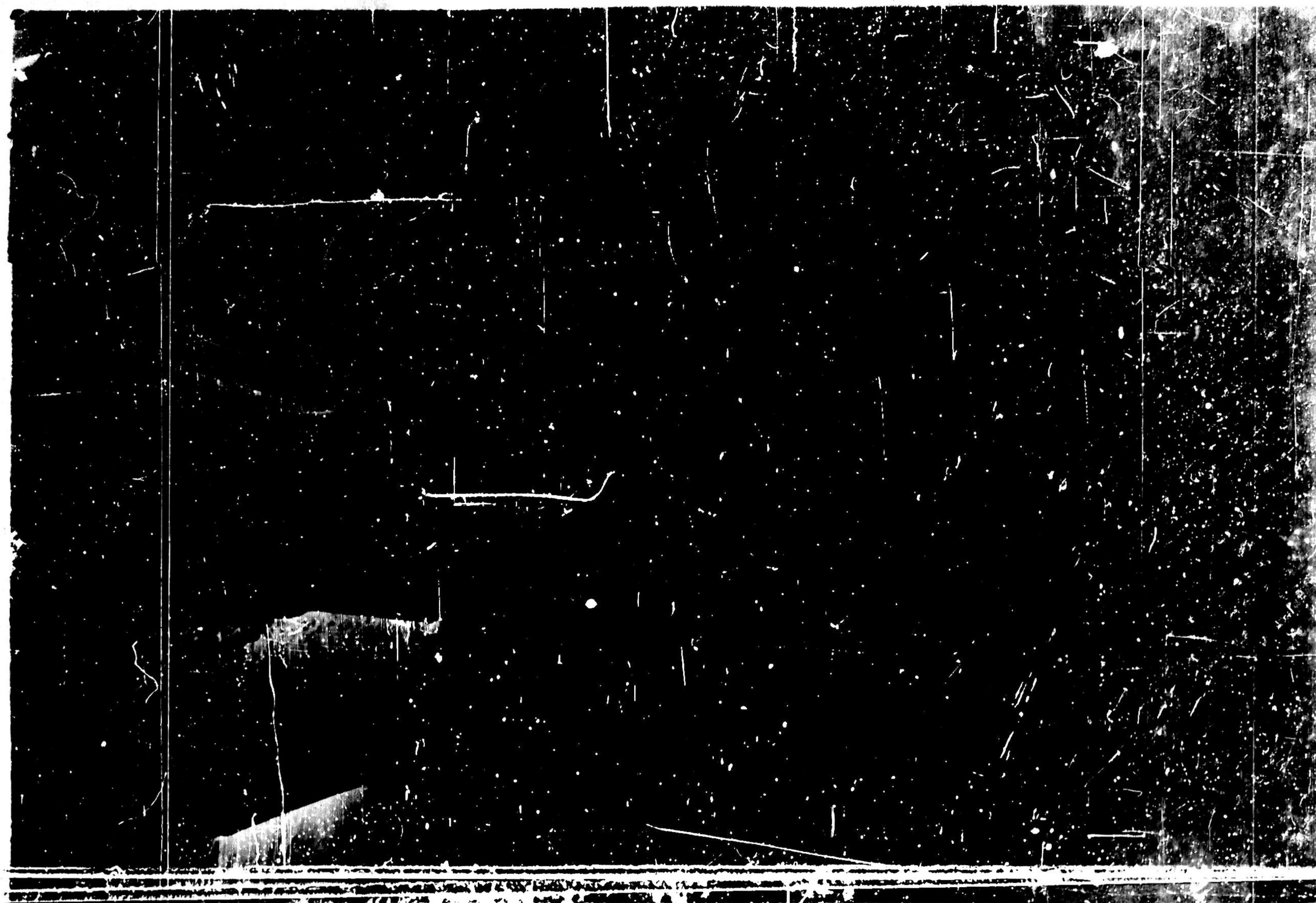

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FIGURE 15 - EXPERIMENTAL 12 GA. MULTI-MISSILE SHOT, CONTAINING [illegible] FLECHETTES, SHOWING ARRANGEMENT AT 3 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE.

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